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Biometeorological Consequences of Environmental Controls: Overview

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On May 14–15, 1974, the National Institute of Environmental Health Sciences (DHEW) and the National Environmental Research Center (EPA) held the third of a series of joint conferences on environmental problems affecting human health. The proceedings of the first conference, on Biological Effects of Ingested Asbestos, were published in Volume 10 of *Environmental Health Perspectives,* and those of the second, on Mobile Air Emissions, constitute the first part of this volume. Participants were invited from the scientific and technological community, announcements were widely distributed, and the sessions were opened to the general public.

The purpose of the conference was to explore instances where unexpected and perhaps unwelcome secondary effects had developed from the application of controls that appeared sound and desirable at the time of their initiation, and to look into ways in which the chance of their happening in the future could be reduced. Particular attention was given to those controls which change meteorological aspects of the environment, and through those changes impose stresses on living organisms, plant, animal or human. Strict boundary lines being foreign to natural systems, the discussion found itself dealing at times with wider issues of environmental controls, but the general impact was maintained.

The conference was organized in three sessions to deal respectively with emissions, housing and land use. Each session in turn dealt with three aspects: current or proposed controls, the meteorological effects of those controls, and their ultimate biological impact, but not necessarily in separate segments.

Principal speakers were asked to submit papers, and these appear in subsequent pages. Rapporteurs noted the highlights of the extensive discussion. This article reviews all of this material and particularly the discussion in presenting an overview of the problems and lessons to be learned therefrom, with only sufficient additional commentary by the writer to round out the concepts presented. The writer, of course, is entirely responsible for the thoughts as expressed; the participants have not had an opportunity to review his synthesis.

Emissions

Some fifteen to twenty years ago the public came to realize that air pollution was not just a matter of historically dirty cities, but was progressively involving and affecting a majority of mankind. Severe episodes like those of Donora in 1948 and London in 1952 and 1962, which were accompanied by markedly increased mortality, underscored the

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threat to human health. But for the more common and chronic situations, effects other than severe threats to human health were the dominant concern. Loss of visibility, deterioration of buildings, damage to domestic finery, offensive odors, and eye irritation had reached unacceptable levels. Health effects, as such, were chiefly evident as an increase in the frequency and severity of symptoms in those who were subject to asthmatic attacks or were suffering from chronic bronchitis. However, the marked effect of emissions on plants in the neighborhood of industrial stacks raised the supposition that what was so bad for plants could not possibly be good for man.

The total effect of these observations was to create in the public mind a sense of urgency that something needed to be done, and done fairly quickly. While it was clear to those who had looked deeply into the problem that we lacked precise information on just how those effects were produced, what the specific toxic agents might be, and how best they could be controlled, it was equally clear that action could not wait indefinitely for better knowledge. Decisions had to be taken, control technology developed, and plans put into execution. These actions undoubtedly brought about some improvement, as residents of London or of the Golden Triangle of Pittsburgh can testify. But, as could only have been expected in view of the speed with which controls were devised, results did not quite match up to expectations.

In the twenty or so years since pollution control was introduced we have had time to take second and third looks at some of the problems. Agents that we thought were important turned out not to be the real culprits; some control technology proved to be less than satisfactory; public demand for goods pushed up emissions as fast or faster than controls could reduce their impact; and the imponderables of dealing with exceedingly complex economic and ecological systems grew more and more evident. Almost any manipulation of a complex system has a distinct chance of producing side effects or repercussions that are unacceptable; perhaps even more unacceptable than the adverse features that one set out to remedy. We find ourselves dealing with at last three exceedingly complex systems: those of pollution, ecology, and economics. Man himself is complex also, so that the preservation of health is not such a black and white affair as some may imagine; and to paraphrase one comment, the real objective of environmental control is to improve human welfare, but human welfare includes economic, social and even esthetic satisfaction as well as health.

Examples

The following examples were among those cited during the conference as resulting in undesirable repercussions.

Substitution of aromatics for lead in gasoline would result in higher local formation of oxidants and potentially carcinogenic polynuclear compounds; the substitution of other metals for lead, such as nickel or manganese, would have equally undesirable consequences.

Oxidation of hydrocarbons in automobile exhaust had led to increased emission of nitrogen oxides, although the magnitude of the potential hazard to health from the latter may have been overestimated.

Catalytic converters in automobiles are apt to turn SO_2 into SO_3 radicals and sulfates, which are now thought to present a greater toxic potential.

Tall stacks may reduce pollution fallout in the vicinity, but do nothing to reduce the total atmospheric burden; their erection has also, unfortunately, been accompanied by greater volume of emissions as production has increased.

In Britain, the greater penetration of sunlight which followed reduction of the classical "pea soup" smog has permitted greater production of photochemical fog components.

A reduction of the larger particulates in air may be creating a false sense of security, since the respirable small particulates have not been correspondingly decreased, and the relatively large surface area presented by

small particles favors adsorption and interaction of atmospheric gases and vapors, with potentially toxic effects.

Relocation of emission-producing industry to rural or semirural sites is bringing about deterioration of the very air to which urban residents could formerly escape.

Recycling of materials increases the demand for fuel, as does a degree of automobile engine inefficiency imposed by anti-pollution devices.

Municipal incineration increases the risk of pollution by metals, organic volatiles, and other potentially toxic products.

Municipal landfill, the alternative to incineration, also has its risks: ground water pollution, vermin breeding, and the evolution of gases even after compaction has taken place and buildings have been erected.

The use of sludge from sewage treatment plants as fertilizer on crop land may result in the entry of trace metals into plants in undesirable amounts.

Selection of plants for resistance to ozone may prove a backward step if, as some contend, stratopheric aircraft reduce the ozone content of the atmosphere.

The installation of antipollution equipment and practices inevitably increases the cost of products, services and equipment. It is quite probable that the additional burden will fall disproportionately on those least able to bear it. For example, poorer people have poorer housing that requires proportionately more heating in cold weather, and less efficient automobiles that require more gasoline per mile travelled, while the cost of fuel has been rising rapidly.

Complexities

The enormous complexity of the systems with which we deal and the limited knowledge that we have about their detailed behavior ran like a threnody throughout the conference. A remark on the presence of unexpectedly high concentrations of ozone in rural air (0.15–0.18 ppm was cited as common) triggered a discussion on its source. It was pointed out that altitude plots show two cells of ozone, one in the stratosphere and one in the troposphere, with a minimum at the 200 mb level. There is more generation of ozone in the tropospheric cell in summer, possibly from the reaction of plant methane with water vapor, but there is more transportation of ozone from the stratospheric cell in winter. It was also pointed out that there is an order of magnitude increase in the ozone content of smog as compared with two to three orders of magnitude increase of nitrogen oxides and carbon monoxide. (Contrary to popular belief, it was stated, there is not much difference in the hydrocarbon content—presumably the speaker was referring to photochemical smog.) There seems to be some uncertainty about the health effects of low concentrations of ozone. It was stated that 0.3 ppm had been shown to have no effect on the health of welders, but that the performance of runners is reduced at 0.15 ppm. Eye irritation often ascribed to ozone in smog is really due to the peroxyacetyl nitrate (PAN). It may be noted that the threshold limit value (TLV) for ozone recommended by the American Conference of Governmental Industrial Hygienists (ACGIH) is 0.1 ppm.

Potential conflict between varying interests in setting standards and enforcement of controls was repeatedly mentioned in this Session. As pointed out by Neligan early in the meeting, action officers find themselves caught between two opposing groups, the one recommending delay until all of the necessary evidence is in, and the other insisting on immediate action. Those who are exercised about environmental preservation press hard for control, often invoking legal constraints; those who have economic commitments to purchasers or stockholders tend to resist the expenditures involved. The argument frequently becomes fragmented, with special interests being pursued out of context, and without due thought for secondary consequences. Echoes of this type of conflict and the necessity for a holistic approach to a

decision will be heard again in the session on land use.

One portion of the discussion turned on the question of who is to be protected—the healthy person, the "average" person, or the susceptible person? At one extreme we can hardly demand that all allergens be removed so that asthmatics will never be stimulated; at the other we can hardly ignore the exacerbating effect of air pollutants on the growing number of bronchitics that age, smoking, and some industrial exposures seem to have created. Each party sees a different goal; there is little or no machinery for the development of a nationally acceptable solution outside of some activities supported by the Federal government, which is not always regarded as the fount of wisdom. The question of what is acceptable goes a-begging.

There is, of course, a bright side to the environmental coin. Neligan introduced the amusing image of a large city struggling with disposal problems if it had suddenly to revert to horse transportation. The automotive engine has certainly speeded the collection and removal of solid waste, as is only too evident when the operators go on strike. Landsberg opined that the dispersion of pathogens in air by an unscrupulous enemy would not be the enormous hazard that we imagine, simply because the organisms would be killed off by the pollution. Kellogg warned in his keynote address that too much emphasis on the undesirable repercussions of past controls might have a depressing effect on the institution of controls in general. The possibility of such a negative effect is underscored by the current pressure for relaxation of controls because of economic stringency.

Courses of Action

A list of alternative strategies is easy to prepare: reduce demand, as is now advocated for energy; substitute innocuous for noxious material—but first be sure that the substitute is innocuous; control emissions by trapping or converting undesirable substances, with due consideration for their disposal; control distribution of emissions so that they are directed away from sensitive locations; screen vulnerable biota (including man) from noxious agents; substitute resistant for vulnerable species—good for plants and fish but hardly applicable to man.

But judging which combination of strategies should be used, and how to apply them, calls for more insight than we seem to have had, or at least to have used. The phrase "more research is needed" has become so hackneyed that in budgetary circles it tends to be counterproductive, but the need cannot be denied. Undoubtedly we have not always used the information that was already available, and there have been many recommendations for improving the flow, and hopefully the use, of information. But it takes very little analysis to show that we sadly lack many critical items, for example: precise information on which of the many environmental agents really pose a threat—as is illustrated by the recent switch of emphasis from sulfur dioxides to sulfates; definition of the levels at which various substances bring about undesirable effects, having regard to the various factors that effect vulnerability, and taking into account dose-time relationships, including the bitter lessons learned in the field of occupational health on the danger of short-term evidence; present and probable future distribution of emissions and the fallout therefrom, together with probable movement of substances through the ecosystem; technology of control that will cope with the various hazards; modes of assessing the repercussions that may develop in the three orders of complexity with which we are dealing (environmental, biological and economic) from the institution of particular control measures.

It was frequently pointed out during the conference that the enunciation of principles is all very well, but that appreciation of their importance tends to be limited to a few. Somehow the general public, as well as the decision makers, has to appreciate not only the need for action but also the great com-

plexity of the systems in which action has to be taken, and the need for arriving at decisions that take into account at least the most significant operators in that complexity. This kind of public education is very far from the simple didactic instruction with which we have long been familiar. In spite of Lord Russel's dictum that nobody uses his capacity for thought to the full, an influential portion of the public has to be led to think about quite complex matters, and to understand that tradeoffs are inevitable. In the long run this may be the greatest challenge.

Nothing less than a change in public philosophy is required. Somehow the polarization that tends to develop on environmental matters must be broken down. Somehow we must learn to live together and, in the words of a familiar advertisement, recognize that there are no simple solutions, only intelligent choices. Choices involve tradeoffs, and tradeoffs imply intelligent weighing of alternatives. It is very difficult at present to get an unemotional and unbiassed weighing of alternatives. Most participants seem to be too concerned with advocating particular interests. As a nation we seem to be wedded to the adversary process and it would be unrealistic to expect its abandonment in favor of sweetness and light. But at some point the adversary approach has to stop and a decision made in light of all of the evidence. To return to Neligan's opening plaint, the decision-maker should somehow be able to shut himself off from pressure by special interests (and environmentalism can be just as special an interest as profit). His decision, furthermore, should be given the same respect as we accord to the judgment of a court. Perhaps what we need is a system of environmental courts; perhaps the environmental impact statement that came in for so much discussion in the subsequent sessions is a step in this direction. The matter will be pursued further in the section on land use.

Housing

Ecology's basic tenet (see paper by Willard) that "everything is connected to everything else" could hardly be better illustrated than by considerations of housing. From the original purpose of providing shelter from climatic rigors, more and more functions have been added as human society has acquired sophistication and the technology to satisfy almost any desire or whim. It was inevitable that the varied desires should develop certain degrees of incompatibility and that the total should exceed individual purchasing power. With our social emphasis on individualism, it was also inevitable that the solution of incompatibilities should be left to haphazard and uninstructed, one might almost say random, decision. Belated attempts to regulate some of the less desirable consequences were bound to encounter strong opposition, and generalized, inflexible ordinances were equally bound to inhibit good as well as prohibit bad variances. The wide ranging discussion of this Session revolved around three main topics: housing as protection against environmental stressors, community and social aspects, and the impact of housing on environmental quality.

Housing as Protection against Environment

In his formal presentation, which appears as one of the following papers, the present commentator reviewed the physical processes involved in the design and use of housing as a barrier to thermal stress, both hot and cold, and indicated some of the ways in which the individual, the architect, or the planner, often with the best of intentions or in the pursuit of some favored feature, failed to satisfy this basic requirement. This century's concept of compensating for design deficiencies by increasing the capacity of heating or air conditioning units was at best a concession to affluence; today it is inadmissible, even in the economy of the United States—it never was admissible in the economic pattern of most other countries.

The increasing number of people with both sophistication and relative affluence during the twentieth century led to greater demand

for two somewhat conflicting requirements: a desire for personal privacy and an attachment to a growing list of appliances, gadgets, household formulas, and medicaments. All of these, in their way, are aimed at improving some part of man's psychosocial environment, but attempts to reconcile their demands have been sporadic and casual; each family has had to resolve its problems or to live with them as best it may. Unfortunately, resolution would usually increase the demand for living or storage space, which in turn would drive up the cost at a time when house financing has become increasingly difficult.

Domestic energy consumption, in the past a matter of urgent concern mainly for the poor, has suddenly become important to everyone, not only by reason of rocketing costs but also through the prospect of actual shortages. Heat leakage in winter, the solar load in summer, inefficiencies of cooking facilities, poorly arranged illumination, and the combined energy appetite of multiple appliances are no longer matters to be met with a frown or a shrug. But housing design, the nature of major equipment, and an established wasteful way of life make curtailment of energy consumption difficult. More attention may be given to these aspects in future planning, but few can contemplate major modifications to what they already have.

Of all the domestic energy consumers, few are more voracious than air conditioners. Worse still, all of the energy fed to the air conditioning equipment, plus all that is removed from the interior, is liberated as heat to the exterior, which in many city cores is already hot to the point that it threatens human effectiveness and even human health. St. Louis and New York City were frequently cited as bad examples, as evidenced by the epidemics of heat deaths in 1966.

Several discussants pointed out that compacted buildings interfere with wind flow, store heat, and frequently house the poor. The heat islands so created, in which summer conditions may approach the limits of human tolerance can be easily driven to exceed those limits by the discharge of heat from air conditioners. If everybody had the benefit of air conditioning the health aspect would not matter so much, although the energy consumption might be prohibitive. But as it is, the Biblical warning, "from him that hath not shall be taken away even that which he hath" (Matt. 25: 29) is unfortunately too true.

Community and Social Aspects

Euston directed attention to the impact of community development on the inhabitants. Echoing a sentiment expressed in the first session, he indicated that about the only way in which we can improve matters is by changing our outlook and habits so that we learn to live together, and make our interactions constructive instead of destructive as now occurs too frequently in crowded areas. The discussion that ensued reminds one of comments on the same problem made in a session on Ecology and Environmental Deterioration at the AAAS-CONACYT meeting on Science and Man in the Americas in June, 1973. Self's paper (unpublished) at that meeting emphasized the point that crowding *per se* produces little effect on health, but that it presents opportunities for mutual exchange and amplification of grievances that can be devastating, and subjects immigrants from rural areas to a social awakening for which they are ill prepared.

The dominant consideration in housing development is usually that of cost (or profit, depending upon one's point of view). Such socially desirable features as convenience, transportation, services, and esthetics tend to be subordinated. In times of financial stringency, which is most of the time for many, the subordination can be extreme. It is unlikely that this state of affairs will change very rapidly. In the meantime, building codes which could preserve these qualities, tend to dwell more on sanitation hazards that were more pressing early in this century, at the expense of adaptation to current social needs. The discussion suggested that regulation of housing other than that

provided by local ordinances comes almost incidentally from the effect of Environmental Impact Statements, such as those required under the National Environmental Policy Act (NEPA). This in turn launched a discussion of the good and bad aspects of environmental impact statements, as a sort of prelude to a more vigorous examination in the succeeding Session.

Not all, however, is neglect or laissez faire. Numerous studies, conferences and community plans were cited, but the impression was left that there was still a long way to go before their ideas and concepts are effectively applied. The inertia is to be attributed, not so much to the practicality of the proposals or recommendations, as to the absence of machinery for implementation. When every local authority has to be convinced of the need for social as well as conventional sanitary considerations, and stimulated to the point of actively insisting upon their implementation, progress is bound to be slow. An example in point is provided by the furor that has developed, even as this commentary is being written, over intensive use of mobile homes and the resultant pollution of ground waters. The national rush to mobile homes is itself a sign of the dominance that cost exercises in the mind of the individual owner as well as in that of the developer. Euston indicated that one cubic foot of space costs some six dollars in an automobile, three to four in a house, and only one and half in a mobile home. Municipalities need to be tough to insist upon environmentally sound location and use in the face of this pressure to minimize costs.

Impact on Environmental Quality

The environmental impacts of housing developments are now evident to almost everybody—spoliation of natural landscapes, speedy runoff of precipitation with increased risk of flooding, erosion of soil during the building phase and later unless proper precautions are taken, risk of pollution from sewage particularly in mobile home sites, automotive exhaust, noise, and accumulation of solid waste. To these items of environmental deterioration must be added decay of city cores vacated by the new residents, and the risk in low cost developments of simply substituting extended slums for the older variety of core slum or the disastrous vertical slums that grace some urban renewal areas.

While it may be objected that these undesirable consequences of housing development are beyond the scope of this conference in being due to lack of control, the fact is that control has been dominated by one consideration—cost. Once the overriding importance of cost is accepted, incentive for effective control over other aspects is lost. Some method is badly needed of assigning a market value to climatic, health and psychosocial features. Environmental impact statements could assist in this process if guidelines to evaluation of these aspects were given. Several suggestions for improvement of environmental impact statements were offered, but there was also some skepticism about the way in which such statements are actually prepared. The various points of view will be taken up in connection with land use, which provoked a lively and wide-ranging critique of the theory and practice associated with this type of documentation.

Summary of Effects

The implications of the session on housing can be summarized as follows.

The original purpose of housing as a means of controlling the domestic environment has been partially subverted by the imposition of other functions ranging from security for possessions to architectural magnificence.

Lack of attention to climatic factors has resulted in dependence upon supplementary corrective heating and air conditioning equipment which consumes relatively large amounts of energy.

Agglomeration of houses into dense core areas has led to the creation of heat islands,

and these are intensified by thermal discharge from air conditioners.

Urban sprawl has increased dependence upon transportation, which adds to air pollution, creates noise, and consumes energy.

Increased energy requirements have increased the probability of air pollution, affecting both urban areas and the hitherto relatively clean environs.

Denudation, erosion and ground pollution, which occur during housing development, are not always brought under control after occupancy.

The psychosocial environment is affected at both ends of the urban spectrum: in dense core areas there is every opportunity for interaction among disaffected residents; in scattered suburbs community interests tend to be focused on local rather than on city affairs.

Regulation of housing development and design is fragmented, subject to special interests out of balance with total needs, and subordinated to cost considerations.

There is an urgent need for the development of a national awareness of the complexity of factors that enter into housing design and planning, and of the deleterious effects of decisions made on the basis of cost alone.

Land Use

In the preceding section it has been pointed out that housing, although used as a means of environmental control since neolithic times, has suffered from fragmentation of concept and design; that the physical principles on which environmental protection rests have been insufficiently observed and their application seldom thought through; and that other demands have been allowed to dominate. In the first session we learned that emission controls by contrast are relatively recent and have been given much more thought, but that the information needed to forsee and avoid undesirable repercussions was not easily available; the intentions were good but the practice was sometimes weak.

Land use, the topic of the third session, has suffered on both counts, and a lot more besides. Attempts to regulate land use have been made from the dawn of history. In the sixth century B.C., for example, enlightened Grecian rulers redistributed land in attempts to break up the power of the aristocracy and to create unified states. In the first century A.D. Domitian tried to regulate the grape crop by decree in order to keep up the price of wine. In this century the Netherlands has severely restricted the subversion of arable land to urban and industrial development. The intentions in these instances, and in most others, have been praiseworthy, but they have usually been directed at some overriding need. The idea of regulating land use in terms of total needs, in order to get the best compromise in a myriad of competing interests, is comparatively new. Attention to total needs is nothing less than ecology applied to human needs, and human needs include, although they should not be dominated by, esthetic and naturalistic considerations.

The modern concept of ecological regulation of land use is thus in an enviable but at the same time a responsible position; enviable because it has a chance to formulate concepts without being tied to past tradition, responsible because all of the varied interests are watching with varying degrees of skepticism to see if it will really work (and not get left behind in the rush to independent action if it falters). If the conference went beyond the legitimate scope of biometeorology to embrace wider aspects of the bioenvironment, it was simply demonstrating the inadequacy of rigid boundaries when applied to ecological affairs.

Objectives of Ecological Control of Land Use

Beatrice Willard, in her opening paper, enunciated the seven keys to ecology: everything affects everything else; there is a wide variety of ecosystems; within an ecosystem everything cycles, except energy which moves

inexorably towards entropy; all ecosystems have definite limiting factors; all ecosystems have a limited carrying capacity; ecosystems go through development stages; and more and more specialized niches develop.

Man disturbs natural ecosystems, it is true, but man himself is part of the ecosystem and has his own needs. The objective of control is to meet human needs while still maintaining a viable ecosystem. The fact that man, or at least some men, want to maintain a balance is itself proof that maintenance of balance is a human need, whatever the motives behind the wish. The very term, land use, implies change, and for that matter nature's "use" involves change; the condition of land is never static. Neither ecology nor land use control implies a completely static condition, although the extreme contentions of some might indicate that they think so. The objective is not to prohibit use, but to keep both the character and the degree of change within bounds, so that a balance is maintained in spite of shifts from the initial equilibrium point. A particular feature affected adversely in one portion of an ecosystem should be carefully preserved in other parts of the same system; the development of towns requires the preservation and perhaps even upgrading of rural environs.

Man, as part of the ecosystem, has his needs, but man depends upon the integrity of the ecosystem for survival, like any other species in the system. Maintenance of the system is not just an emotional protectiveness on the part of a few individuals, but a necessary condition for man's continuance. Irreparable damage to the system can jeopardize that continuance. Perhaps some infinite wisdom could name a few small components that could be removed without jeopardy to the whole, but man has hardly arrived at the stage of infinite wisdom. Until proved otherwise, and strictly on the basis of logic, all components must be regarded as essential; we remove them at our risk.

Examples of Unbalanced Action

Instances of actions taken without sufficient regard for other ecological needs have been cited in preceding sections of this overview. The following additional instances were brought up in the session on land use.

A cypress swamp near an atomic energy plant actually accepted an unnatural load of ^{123}Cs, but this undeserved bonus was liquidated when the addition of well water upset the pH and permitted the cesium to be liberated from the underlying kaolinite on which it had been adsorbed.

Filling of coastal wetlands for development purposes destroys the breeding ground for important species in the estuarine food chain that ultimately determine the fishery potential. Odum was quoted as estimating that one acre of costal land is worth $85,000 per year in its contribution to the productive return of the ecosystem.

There are frequent reports of coastal buildings becoming prey to encroachment by the sea, a reminder of a very old warning about the futility of building a house on sand.

Restriction of forest fires limits the germination of some seeds that require the heat for opening of the seed pods. Uncontrolled fires can be destructive, but their effects need to be duplicated with local controlled fires if succession is to be maintained.

Introduction of species with brittle timber into forests even occasionally visited by snow and ice can lead to disastrous destruction.

Extensive cutting of redwoods on upper slopes has led to increased runoff and accumulation of eroded soil on trees of lower slopes, producing gradual deforestation.

Since building on rocky terrain is more difficult, housing and industrial developments tend to use areas with good soil that might better be given over to agriculture or park land.

Agricultural plantings in northern latitudes may not conform to the constraints of natural thermoclines. Unusual plantings may actually change thermal conditions to the disadvantage of other species.

Damming of the Great Lakes for the St. Lawrence seaway has resulted in increased

fresh water content of the lakes, with adverse effects on the fish.

Planting of pine trees may not be compatible with agricultural use of the soil because of the acidity that they produce.

Many more instances would undoubtedly have been adduced had time been available. Conservation literature has made them very familiar. The important matter that the conference was asked to consider is how mistakes like these can be avoided, or at least minimized, in the future.

Environmental Impact Statements

Conferences on land use are now commonplace at federal, state and local levels. But the greatest impetus to attention, and one which has partially prompted such conferences, is the requirement by the National Environmental Policy Act, of 1969 (NEPA) for the presentation of Environmental Impact Statements (EIS). The relevant wording of Section 102(2)(C) is as follows:

> ". . . all agencies of the Federal Government shall . . .
>
> (C) include in every recommendation or report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment, a detailed statement by the responsible official on
>
> (i) the environmental impact of the proposed action,
>
> (ii) any adverse environmental effects which cannot be avoided should the proposal be implemented,
>
> (iii) alternatives to the proposed action,
>
> (iv) the relationship between local short term uses of man's environment and the maintenance and enhancement of long term productivity, and
>
> (v) any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented."

Provision is made for input from state and local agencies which are authorized to develop and enforce environmental standards. Copies of all statements, comments and views are to be made available to the Council on Environmental Quality as set out in Beatrice Willard's paper. The idea has spread to other countries, to the point that the Scientific Committee on Problems of the Environment (SCOPE), of the International Council of Scientific Unions (ICSU), has held an international conference (February, 1974) and has published a book entitled, "Environmental Impact Assessment: Principles and Procedures (Scope 5)."

The intentions of the legislation and of the principles enunciated are quite clear, but the mechanics of application are still evolving. As was only to be expected, those who were required to develop statements have expressed some unhappiness with the labor involved and with forseeable restrictions on freedom in development. In the absence of past experience with such provisions, uncertainties and difficulties arose when the legislation came to be implemented. That the difficulties have not been entirely resolved was evident from the amount of discussion that this topic evoked in all three sessions. A number of comments and criticisms were advanced, some as personal opinions of the participants, others as examples of complaints that they had received. The following, ranging from the cynical to the helpful, are illustrative of the general reaction.

An EIS as currently prepared is frequently a set of clichés thrown together to meet what the compiler considers to be just another set of bureaucratic requirements; or it may be a self-serving document designed simply to justify what the proponent intends to do anyway.

Some take the attitude that politics and money will make the decision anyway, so why bother with a laborious statement? Others, a little less cynical, believe that what the public wants, the public will get, whether or not it is ecologically wise, so again why bother?

Some cloak their cynicism in somewhat softer terms and ask who makes the final judgment, and what role does cost play in the judgment?

The anonymity of the EIS plays into the hands of those who wish to dull the edge of

the legislation by statements that fail to reveal what degree of competence went into their preparation.

The factors to be taken into consideration are too numerous and their interrelationships too complex for any rational decision to be taken. The intention of the legislation goes beyond our ability to handle the complexities involved.

Proponents do not know how to reconcile conflicting needs. For example, is air pollution from automobiles to be curbed at the expense of providing transportation? In another time frame, is a long-term solution to be sought at the expense of short-term crises? In terms of a current problem, should workers be thrown out of employment by the closure of a plant that may pose a health hazard thirty years from now?

How are the requirements of the numerous agencies at federal, state and local levels to be satisfied when they conflict? Is all development to be suspended until all entanglements are cleared?

The delay involved in preparing an EIS, and the cost of meeting ecological requirements, are inhibiting low cost construction in which the profit margin is slim. Will this negative effect on development of housing for the poor be considered in the making of a judgment?

It should be a requirement that the EIS contain, not merely lists of relevant factors, but quantifiable estimates of their magnitude and relative importance. Too much of current environmental advocacy concerns items of minor or unproven importance.

The EIS is not currently required to take into account long range responsibilities or contingencies, such as the bankruptcy of the operator, changed market demands for products, or new information on what constitutes an ecological hazard.

Information should be included on the level at which a particular factor constitutes an important hazard, and on its potential reversibility.

There is no provision for assessment of the effectiveness of a particular requirement, and no body of past experience to serve as a guide. There should be some machinery for periodic surveillance of the effect of controls and provision for their modification in the light of that surveillance.

Those participants who had been involved in the framing of EIS legislation and guidelines were quick to fly to their defense, and pointed out that there were no past precedents on which to base day-to-day procedures and decisions, and that in the four years since the enactment of NEPA much of the initial confusion had been cleared up. The comments and complaints fall into five categories. First, there is a certain amount of natural negativism which time alone will cure, and there are signs that it is already being reduced. Second, certain adjustments need to be made in procedures, and we have the assurance of the agencies involved that improvements are being made. Third, when it comes to decision-making, everyone will admit that we are still learning. However, mathematical and judgmental techniques are constantly improving, and it is becoming increasingly possible to select out from a large number of factors those which are of particular importance, and reduce them to a manageable number. Fourth, in the matter of political and fiscal considerations it would certainly be unrealistic to claim that they have disappeared from the scene, but they are having to face up to an increasing volume of hard ecological fact and (hopefully) an improved public understanding of the issues involved. As in all complex situations, some kind of compromise has to be sought between conflicting objectives, each worthy in itself but not capable of complete satisfaction in the presence of others. This is a difficult area in which no rules can be laid down, and it certainly holds occupational hazards for those who have to make the decisions. We can only hope that those who have this responsibility will be permitted to act in independent fashion and to build up such a reputation for integrity that their judgments will be respected, even if at times they prove impractical or even mistaken.

Conferences such as this one can provide a forum for ventilation of doubts and explanation of the bases for compromise and trade-off. But the best of intentions cannot be productive unless the fifth category of points raised is given very serious attention: the acquisition of sound information on which to base judgments.

Information Needed

The one point on which there was substantial agreement between all parties involved is that the information needed to write a really satisfactory EIS is seldom available. The general principles are fairly clear, and quantities can be fairly well ascribed to some of the factors involved, such as the increased rate of runoff to be expected in a built-up area. However, when it comes to second- and higher-order effects, such as the multiplication of fish in estauaries fed by drainage from those areas, or the extent to which removal of plant cover will irreversibly affect the vegetation of the environs, the data on which to base a prediction are scanty. Opinions can be advanced, but opinions are poor weapons with which to confront balance sheets. Among the areas of knowledge and predictive techniques that need development one may cite: techniques for selecting the most influential from among the several factors that are operating in a given ecosystem; techniques for determining the probable result of the interplay between several competing factors; catalogs of dominant factors and of vulnerable species in typical biomes; methods of estimating reliable cost/benefit ratios of a proposed action or control measure, having regard to conservation of existing components, maintenance of a viable ecosystem in the presence of change, the development of compensatory features in other parts of the ecosystem, and the benefits to be gained from proposed change; ways of evaluating what the result of a particular departure would be for the ecosystem in question; allocation of comparative values to such desiderata as health, longevity, productivity, and self-realization.

This is not to say that we are completely ignorant on these matters, or that action must be postponed pending enlightenment. There is a substantial body of knowledge in each of these fields, and at least tentative or "best judgment" estimates can be made. But considerable improvement is necessary if decisions are to be made with the confidence that some would demand and all would desire.

Modelling

A number of the techniques that are being applied to the analysis of complex and dynamic systems can be subsumed under the general title of modelling. A model may be described as a set of relationships believed to represent the essential structure of the system under study, into which specific values can be entered, and with which the effect of a particular operation, such as a change in some values or the introduction of a new parameter, can be calculated. Various mathematical techniques may be employed, usually with computer aid, such as network theory, linear or dynamic programming, gaming, etc.

Liff presented the results of predictive modelling applied to proposed highway developments in and around Baltimore, Md. In the short time available it was not possible to go into the mathematical details, but the results presented were impressive. A surprisingly large number of variables were taken into consideration, more than the paper itself suggests. Those who were familiar with modelling had many technical questions, and several characteristics of modelling in general were brought out in the discussion. As one participant pointed out, the large amount of information collected on socio-economic as well as physical aspects of the environment were alone worth the effort expended, since they are needed for numerous other development problems. The ability of a good model to handle different sets of values was emphasized, such as vari-

ous types of compromise strategy decisions or a change in the type of labor utilization, to see what differences might be produced in the traffic flow and attendant environmental disturbances. There was some discussion on the values to be assigned to certain variables; for example, is a population increase to be treated as a desirable event on account of the increased tax base, or is it a negative factor on account of the socio-economic burden that it places on the community?

There are, of course, certain dangers in the use of models. The human tendency to push any system beyond the limits for which it was designed needs to be watched. A model designed to deal with generalized changes over a region, for example, can be expected to give no more than probable trends for a limited area within that region. There are too many microclimatic and other local pecularities that could produce perturbations over limited areas. Ecologists have an innate, and justifiable, fear that planners may be tempted to adopt the easy philosophy that technology can do better than nature, or, if you will, that the computer knows best. All human judgments are liable to error, but those made in modelling are apt to be applied to large undertakings with proportionately disastrous results.

Historically, a model was a physical representation of a system rather than a set of equations, and this type of modelling has not lost its importance in spite of being in the shadow of its more glamorous cousin. The plea was made that both modes be used in symbiotic fashion, with the most probable values established by physical modelling being entered into the larger systems of mathematical modelling. One such presentation from the floor indicated that numerical models are able to provide general wind fields and hence evaluate diffusion as a function of time and space for grids upward of 1 km. Wind tunnels and water channels offer assistance for scales below 10 km. Atmospheric flows with little or no wind shear under neutral through unstable conditions can be simulated in the wind tunnel, while slightly stable atmospheric boundary layers can be simulated in a water channel. However, neither physical models nor simple diffusion models are particularly useful for "worst case" stagnation conditions. Here, three-dimensional, predictive models of the urban flow field are required. Parameterization of turbulent exchanges below the 1 km scale or grid increment must be accomplished by an interactive program involving physical and numerical models and field measurements.

Conclusion

The conference fully justified the hopes of the organizers in progressing from the rather specific matters of emission control, through housing, to land use with increasing interaction, until a truly ecological approach to multifactorial stiuations dominated the final hours. The dangers of simplistic approaches to what might appear to be individual envoronmental problems were clearly illustrated, and the necessity was demonstrated of impressing this fact upon both planners and the public, so that the practice will become the rule rather than the exception, and problems will be examined in ecological perspective.

Within the limits of the time available, ways of handling the complexities were discussed and the role of the Environmental Impact Statement was thoroughly and constructively examined. Not the least of the benefits deriving from the conference was the opportunity that participants had to meet with people who are facing similar problems in other fields, people whom they otherwise would not be likely to meet. The impression was gained that this type of interdisciplinary conference on environmental problems could play an important role in bringing together the various approaches needed for satisfaction of ecological requirements.

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